# Eastern Interconnection Wind Integration and Transmission Study

# Technical Review Committee Meeting #2 "Getting to know our wind data"

October 8, 2008 Chase Center Wilmington, DE



#### Robert Zavadil

Vice President and Principal Consultant 620 Mabry Hood Road, Suite 300 Knoxville, Tennessee 37932 Tel: (865) 218-4600 ext. 6149 bobz@enernex.com www.enernex.com

# **Morning Agenda**

8:30 am	Welcome & Introductions	Dave Corbus (NREL)
8:40 am	Meeting Overview & Objectives	Bob Zavadil (EnerNex)
9:00 am	Analysis and Characterization of Eastern	Jack King (EnerNex)
	Interconnection Wind Data	
	"Getting to know our wind data"	
	<ul> <li>Geographic definitions</li> </ul>	
	<ul> <li>Wind Characteristics</li> </ul>	
	<ul> <li>Load net Wind Impacts</li> </ul>	
	<ul> <li>Regional Wind Metrics</li> </ul>	
10:30 am	Break	
10:45 am	Developing the Conceptual Transmission Overlays	JT Smith (MISO)
	<ul> <li>Case definitions (JT Smith)</li> </ul>	John Lawhorn (MISO)
	<ul> <li>Economic Transmission Expansion Process</li> </ul>	
	(John Lawhorn)	
	<ul> <li>Task 3 plan and schedule</li> </ul>	
	<ul> <li>Issues and challenges for this study</li> </ul>	
11:45 am	Lunch	



# **Afternoon Agenda**

12:45 pm	Methodology for Consideration of Intra-Hourly Operational Issues	Bob Zavadil (EnerNex)
	What we are trying to capture	
	<ul> <li>Mathematical and statistical analysis</li> </ul>	
	Reserves & fast markets	
	<ul> <li>Mapping to hourly production simulations</li> </ul>	
1:45 pm	Hourly Production Simulations – Approach, Issues,	Gary Moland (Ventyx)
<b>p</b>	and Assumptions	
	<ul> <li>Assumptions in "Normal" production simulations</li> </ul>	
	<ul> <li>Capturing uncertainty impacts</li> </ul>	
	Reserve issues	
	<ul> <li>Challenges to address for this study</li> </ul>	
	<ul> <li>Plans and schedule</li> </ul>	
2:30 pm	Break	
2:45 pm	Proposed Scenarios	EnerNex
	• 5% Reference Case	
	<ul> <li>Economic transmission concept?</li> </ul>	
	<ul> <li>Reliability upgrades only?</li> </ul>	
	<ul> <li>20% Base and Alternate</li> </ul>	
	<ul> <li>30% Base and Alternate</li> </ul>	
3:15 pm	Discussion	Matt Schuerger (NREL)
4:00 pm	Wrap-Up	Matt Schuerger (NREL)
	<ul><li>Issues</li></ul>	
	<ul> <li>Summary of Action Items</li> </ul>	
	<ul> <li>Logistics</li> </ul>	
4:30 pm	Adjourn	
	EWITS Technical Review Committee Meeting #2	



### **Meeting Objectives**

- Review Wind Data Characterizations
- Present approach and process for developing conceptual transmission overlays
- Review methodology for intra-hour analysis
- Discuss issues related to production modeling for assessing wind integration impacts
- Present proposed wind generation scenarios
- Revisit assumptions for production modeling and reliability analysis



# CHARACTERIZATION AND ANALYSIS OF EASTERN MESO-SCALE DATA



### **Task 1: Preliminary Analysis**

### Objective

- Characterize meso-scale wind production data from NREL dataset
  - » Production attributes
  - » Energy value
  - » Issues for delivery
- Define base and alternate scenarios for 20% and 30% penetration by energy in Eastern Interconnection

» 20%: 240 GW

» 30%: 360 GW

### Issues

- Full mesoscale data set not available until end September
- Next TRC scheduled for <mid-October</li>



### Approach for Analyzing Mesoscale Data

- a) Group wind sites into 20-30 regions.
- b) Conduct statistical analysis with spatial and temporal slices, to examine resource correlation across the region and wind/load correlation over time.
- c) Examine the energy production value of wind sites.
- d) Examine the transmission capability between wind regions.
- e) Develop preliminary costs for each wind region based on statistical analysis, production value, and transmission capability.

#### -----TRC Meeting #2 will be here-----

- f) Develop two scenarios with 20% and 30% wind energy penetration in the study footprint based on these analyses, and with a goal of low cost of energy and low integration costs.
- g) Conduct statistical analysis on these two scenarios to examine the feasibility of integrating these levels of resources into the individual control areas.
- Analyze two variations of the 20% and/or 30% wind energy scenarios (2 additional scenarios) to address stakeholder issues. These two additional scenarios may include variations in the geographic spread of wind plant sites, a "best correlated with load" scenario; a scenario that looks at least-cost transmission considerations, and other scenarios as identified by the TRC.
- i) Present the preliminary analysis and proposed scenarios to the TRC.



# **Count of Plants by Size**

Plant Size	
(MW)	Count
0 -150	265
150 - 250	155
250 - 350	214
350 - 450	194
450 - 550	146
550 - 650	95
650 - 750	52
750 - 850	38
850 - 950	11
950 - 1050	57
1050 - 1150	54
1150 - 1250	29
1250 - 1350	12
1350 - 1450	3



## Number of Plants by Size and State

		150 -	250 -	350 -	450 -	550 -	650 -	750 -	850 -	950 -	1050 -	1150 -	1250 -	1350 -
State	0 - 150	250	350	450	550	650	750	850	950	1050	1150	1250	1350	1450
Arkansas	11	6	2							1				
Colorado			2	3	1		1	1						
Connecticut	6	2												
Delaware	6		1											
Illinois		5	19	23	6	5	2	5	2	6	4	1	1	
Indiana		5	17	12	9	6	3	1		3	4	1		
Iowa		7	13	17	17	13	6	6	1	4	1	2	4	1
Kansas			6	12	10	10	5	3	1	1	11	5	2	
Kentucky	3		1	1	1									
Maine	37	4									1			
Maryland	7	2												
Massachusetts	18	1												
Michigan	9	13	12	5	5	1	3	1	1	3	1	2		1
Minnesota	1	9	33	22	22	13		4	1	4	7	4	1	
Missouri		1	4	4	2	5			1	1	1			
Montana	2	2	2	2	1				1	1				1
Nebraska		8	16	17	13	9	8	3		10	4	1		
New Hampshire	20	1												
New Jersey	5	2		1										
New Mexico	2	5	4	3	5		2		1	1	1			
New York	25	26	5	5	1		2	1			1			
North Carolina	6	2		1	1									
North Dakota		6	13	10	10	6	3	2		5	3	2		
Ohio		4	9	4	4	2	6	1		1	2	1		
Oklahoma	4	9	14	21	11	7		5		5	4	1	1	
Pennsylvania	48	7	1											
Rhode Island	4	3												
South Dakota	2	9	14	18	13	13	6	2	2	5	4	2	1	
Tennessee	7	1												
Texas			11	8	6	4	3	1	1	2	4	6	2	
Vermont	14	3												
Virginia	13	1	2											
West Virginia	15	2		1										
Wisconsin		8	14	4	8	1	2	1		4	1	1		



### **Total Plant Capacity by Size and State**

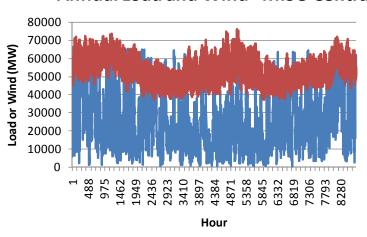
	0 - 150	150 - 250	250 - 350	350 - 450	450 - 550	550 - 650	650 - 750	750 - 850	850 - 950	950 -	1050 -	1150 -	1250 -	1350 -
State										1050	1150	1250	1350	1450
Arkansas	1342	1101								1049				
Colorado			541	1191	456		732	840						
Connecticut	685	346												
Delaware	688		330											
Illinois		1162	5776	9076	3021	2854	1357	3979	1747	6164	4370	1234	1291	
Indiana		1135	4963	4878	4564	3663	2181	823		3104	4456	1199		
lowa		1595	3989	6895	8474	7798	4081	4762	919	4024	1107	2414	5083	1435
Kansas			1778	4936	4997	5918	3441	2418	906	1011	12153	5930	2581	
Kentucky	300		264	381	545									
Maine	4026	753									1084			
Maryland	769	345												
Massachusetts	1998	168												
Michigan	1029	2671	3508	1992	2470	578	2107	797	896	3085	1082	2369		1361
Minnesota	147	2036	9839	8973	10774	7726		3209	880	4075	7762	4777	1281	
Missouri		245	1316	1658	950	2907			878	1038	1147			
Montana	269	463	598	772	497				850	1025				1357
Nebraska		1875	4708	6792	6289	5279	5509	2273		10209	4366	1171		
New Hampshire	2188	183												
New Jersey	548	357		423										
New Mexico	203	1076	1161	1207	2396		1418		897	1038	1128			
New York	2756	4992	1373	1934	516		1377	825			1086			
North Carolina	642	386		425	546									
North Dakota		1267	4016	4035	4879	3500	2141	1570		5121	3222	2388		
Ohio		822	2715	1540	1892	1194	4098	795		969	2212	1207		
Oklahoma	400	1927	4179	8295	5336	4222		4016		5062	4361	1163	1291	
Pennsylvania	5517	1176	294											
Rhode Island	462	578												
South Dakota	271	1847		7279	6376	7708	4247	1529	1772	5047	4480	2374	1304	
Tennessee	730	156												
Texas			3317	3142	2874	2440	2176	789	890	2046	4413	7196	2613	
Vermont	1537	482												
Virginia	1340	197	561											
West Virginia	1543	430		403										
Wisconsin		1611		1597	3940	560	1397	753		4035	1125	1230		



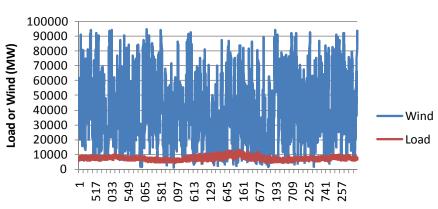
# **Great Plains and Midwest Load & Wind Potential**

#### **Annual Load and Wind - MISO West** Load or Wind (MW)

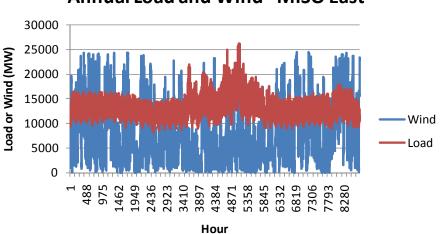
**Annual Load and Wind - MISO Central** 



#### **Annual Load and Wind - MRO US**



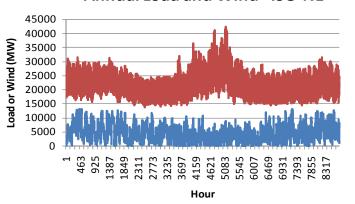
**Annual Load and Wind - MISO East** 



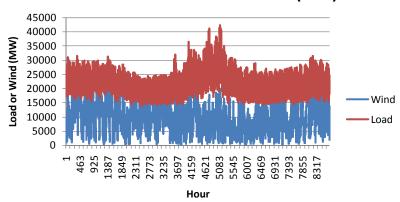


### **Northeast Load & Wind Potential**

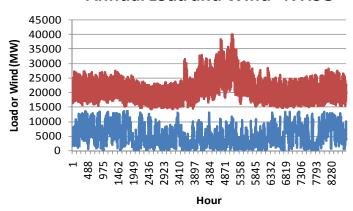
#### **Annual Load and Wind - ISO-NE**



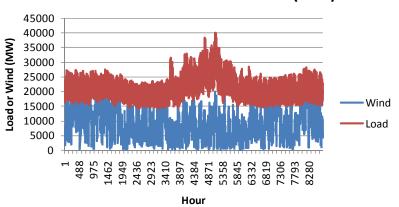
#### Annual Load and Wind - ISO-NE (Wet)



#### **Annual Load and Wind - NYISO**



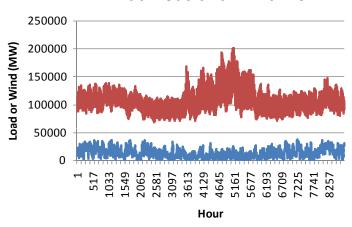
#### Annual Load and Wind - NYISO (Wet)



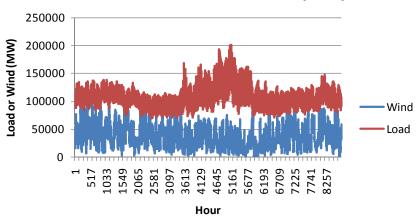


### PJM & SPP Load & Wind Potential

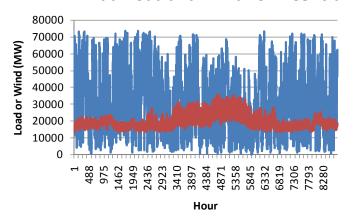
#### **Annual Load and Wind - PJM**



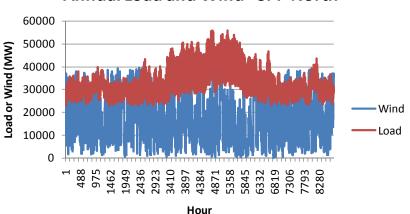
#### Annual Load and Wind - PJM (Wet)



#### **Annual Load and Wind - SPP Central**



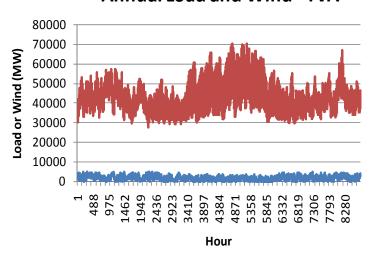
#### **Annual Load and Wind - SPP North**



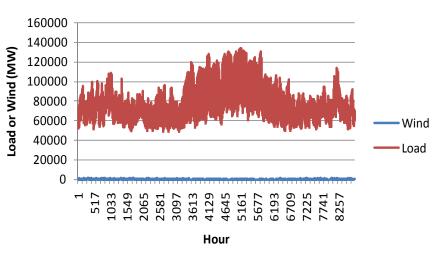


### TVA and SERC Load & Wind Potential

#### **Annual Load and Wind - TVA**

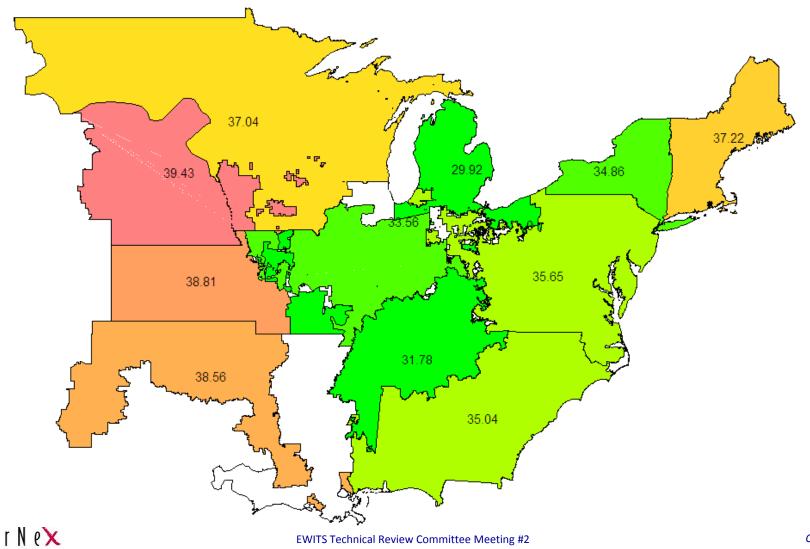


#### **Annual Load and Wind - SERC**

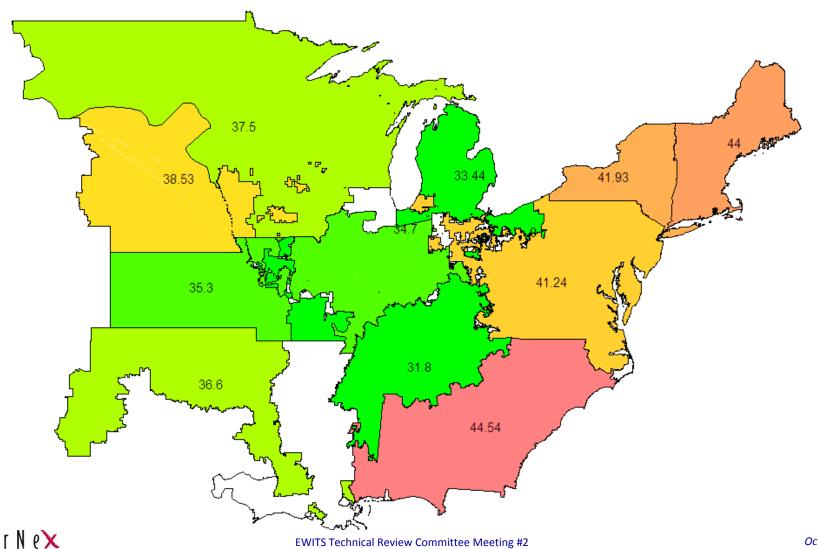




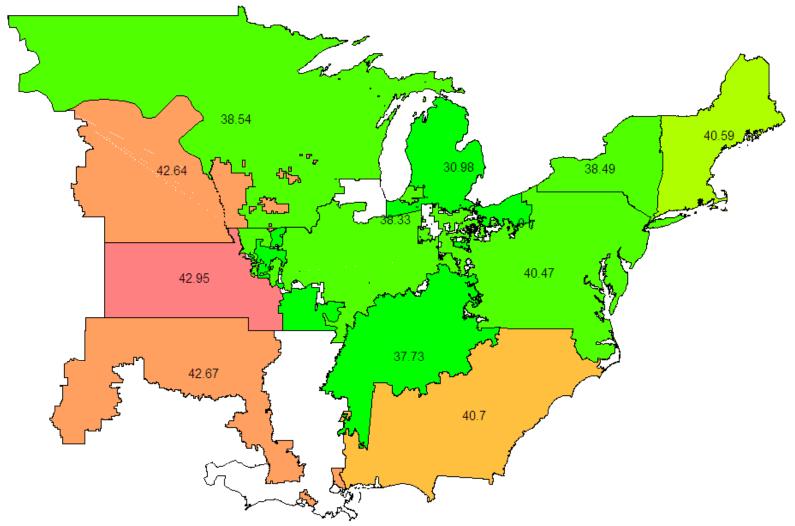
## **Capacity Factor - January**



## **Capacity Factor - February**

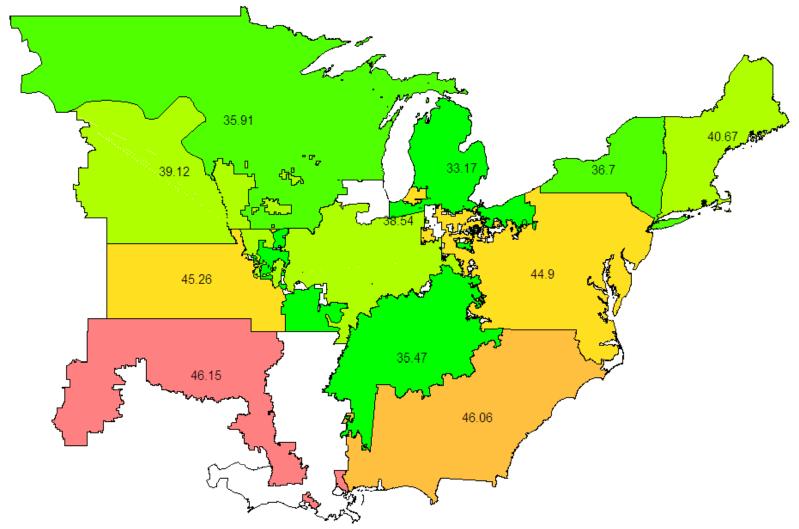


## **Capacity Factor - March**



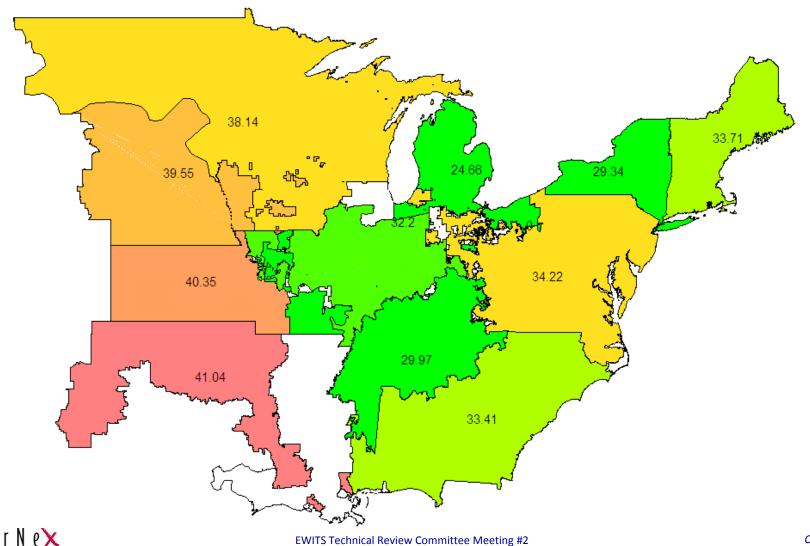


# **Capacity Factor - April**

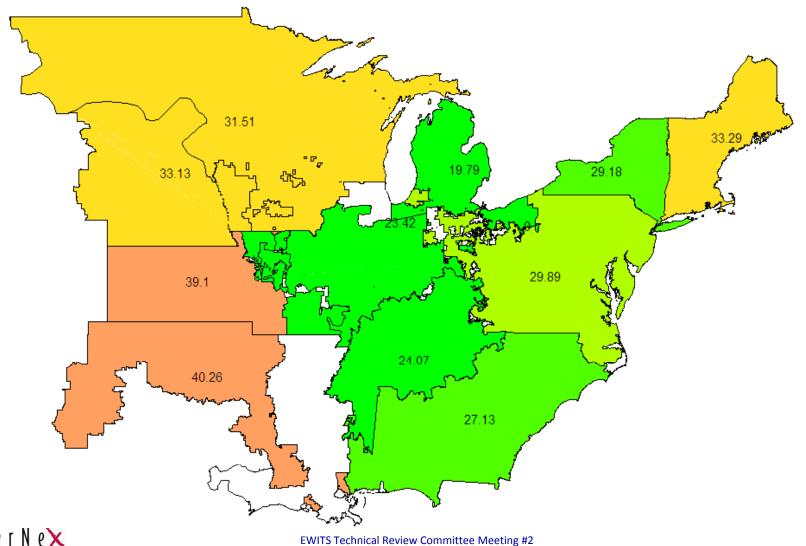




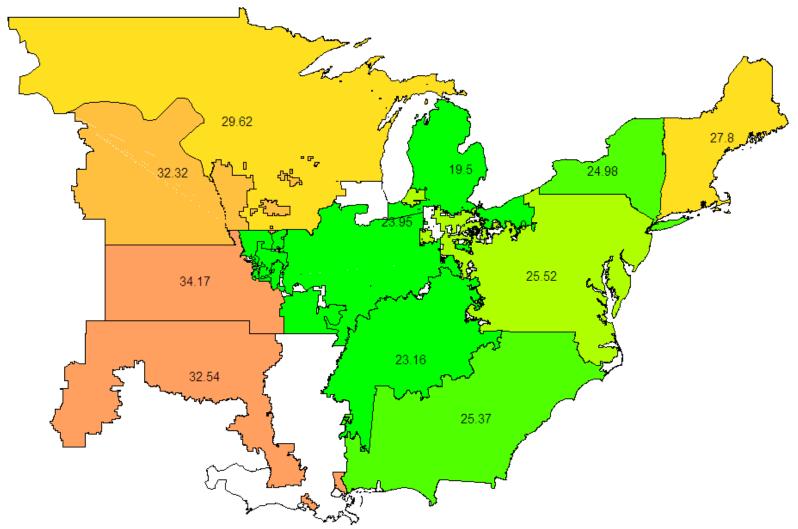
# **Capacity Factor - May**



# **Capacity Factor - June**

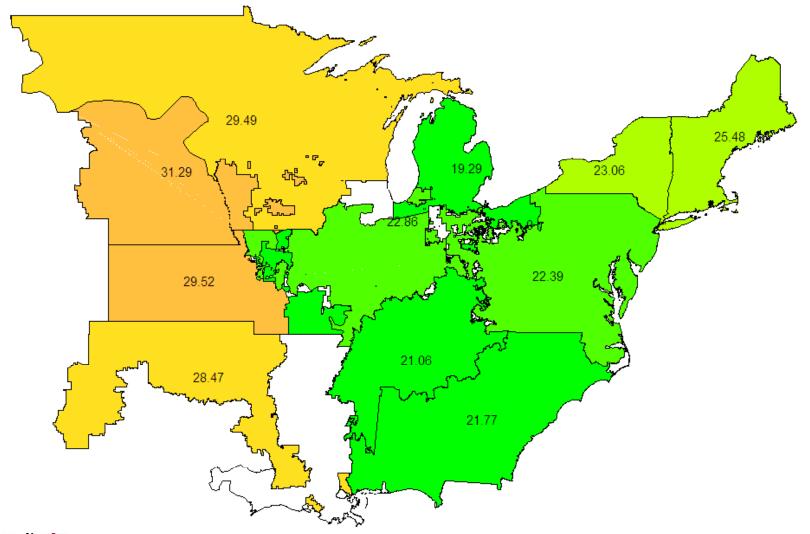


# **Capacity Factor - July**

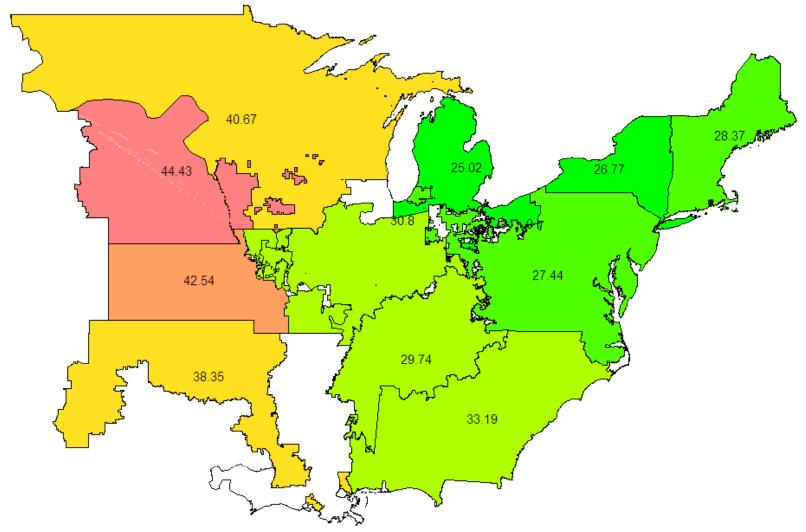




## **Capacity Factor - August**

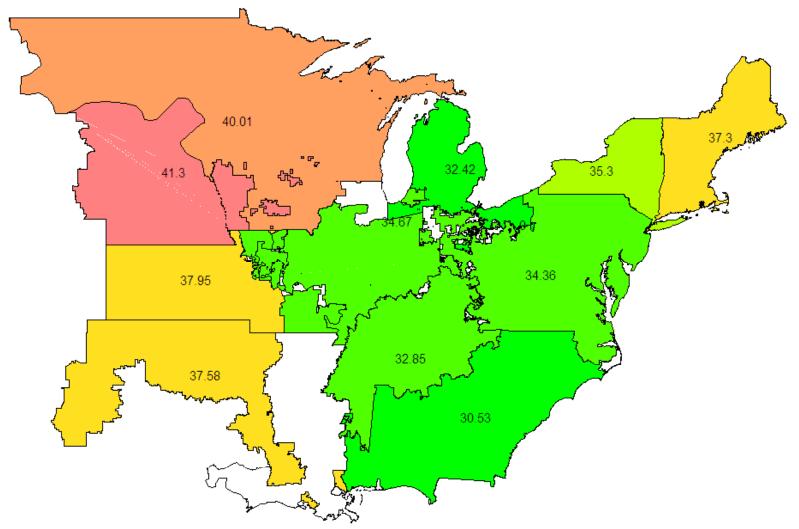


# **Capacity - September**



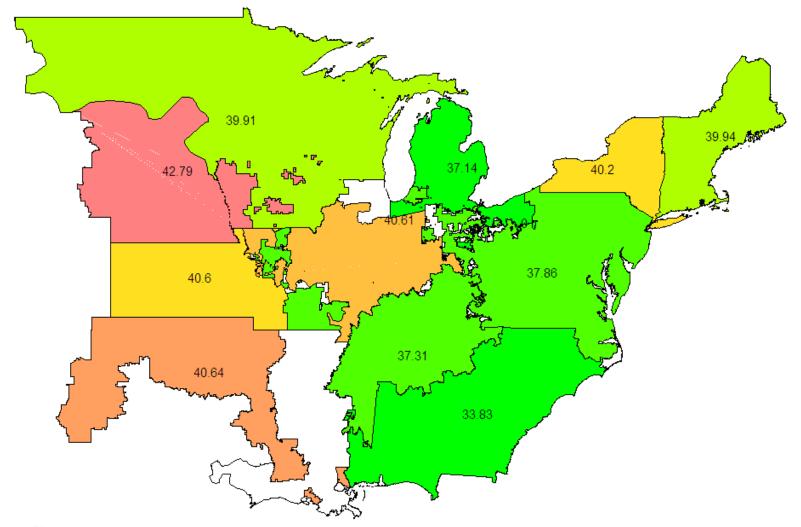


# **Capacity Factor - October**



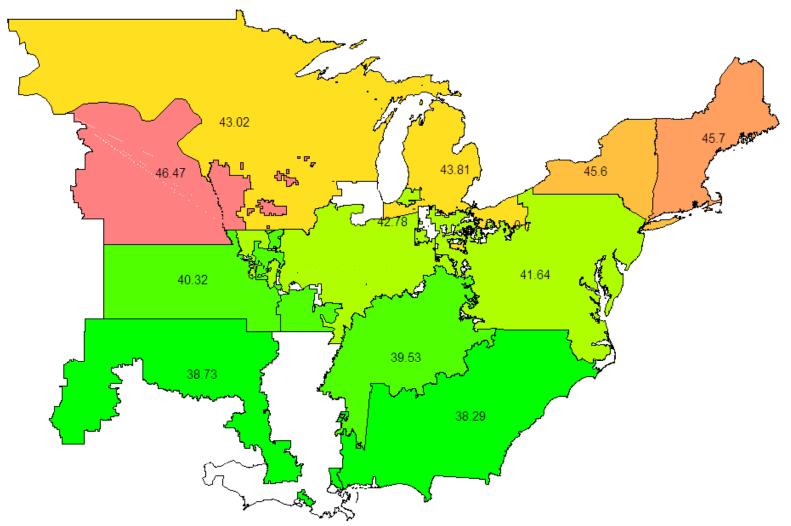


## **Capacity Factor - November**





### **Capacity Factor - December**

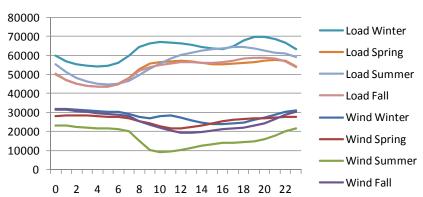




### **Northern Great Plains and Central US**

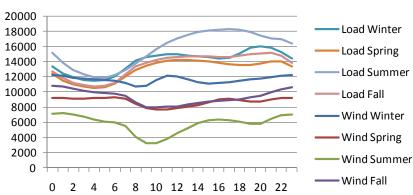
#### **Average Production Profile By Season**

- MISO Central with Offshore



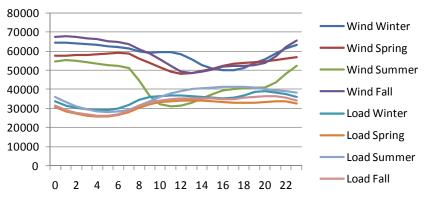
#### **Average Production Profile By Season**

- MISO East with Offshore



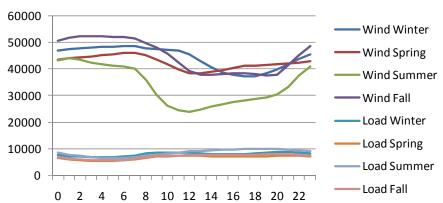
### **Average Production Profile By Season**

- MISO West with Offshore



### **Average Production Profile By Season**

- MRO US with Offshore

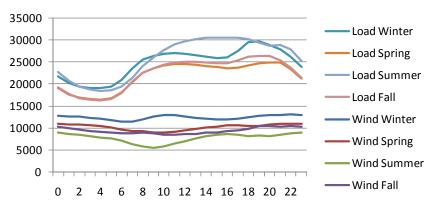




### North and Eastern US

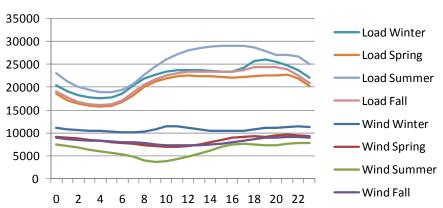
### **Average Production Profile By Season**

- NE-ISO with Offshore



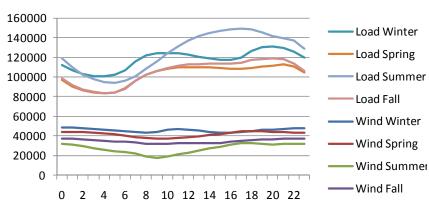
#### **Average Production Profile By Season**

- NYISO with Offshore



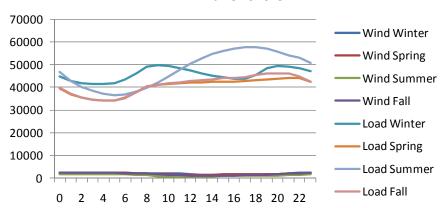
### **Average Production Profile By Season**

- PJM with Offshore



### **Average Production Profile By Season**

- TVA with Offshore



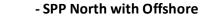


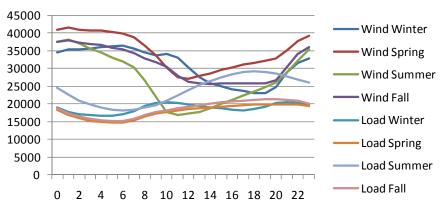
### **SPP & SERC**

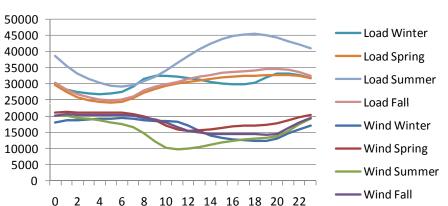
#### **Average Production Profile By Season**

### **Average Production Profile By Season**



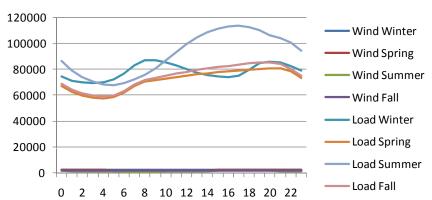






### **Average Production Profile By Season**

#### - SERC with Offshore

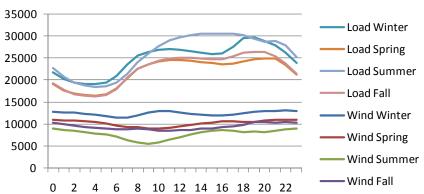




### **Effect of Offshore Wind**

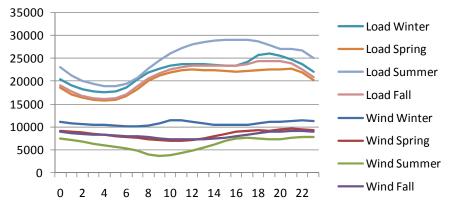
### **Average Production Profile By Season**

- NE-ISO with Offshore



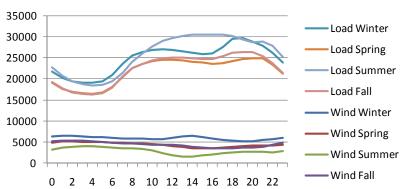
### Average Production Profile By Season

- NYISO with Offshore



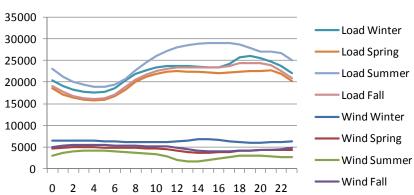
### **Average Production Profile By Season**

- NE-ISO No Offshore



#### **Average Production Profile By Season**

- NYISO No Offshore

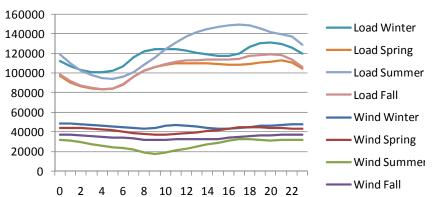




### **Effect of Offshore Wind**

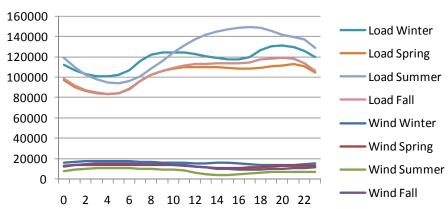
#### **Average Production Profile By Season**

- PJM with Offshore



#### **Average Production Profile By Season**

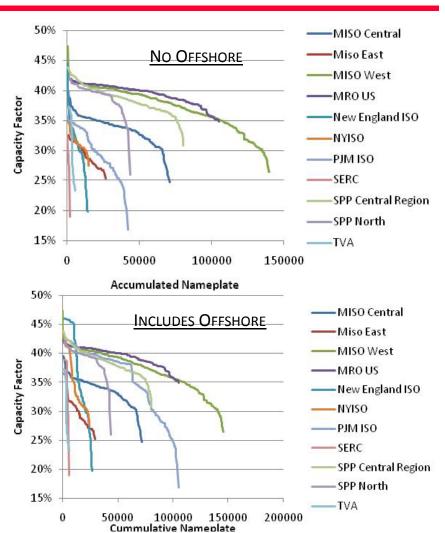
- PJM No Offshore





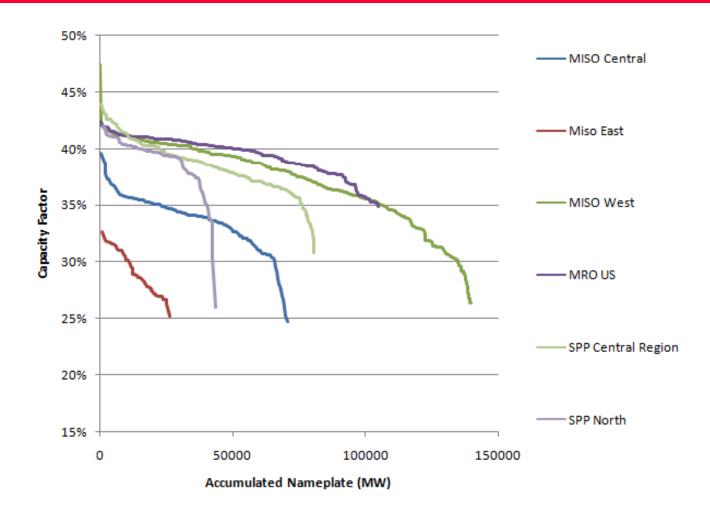
### **Supply Curves by Capacity Factor**

- Energy cost direct function of capacity factor
- Curves include all plants in NREL mesoscale database



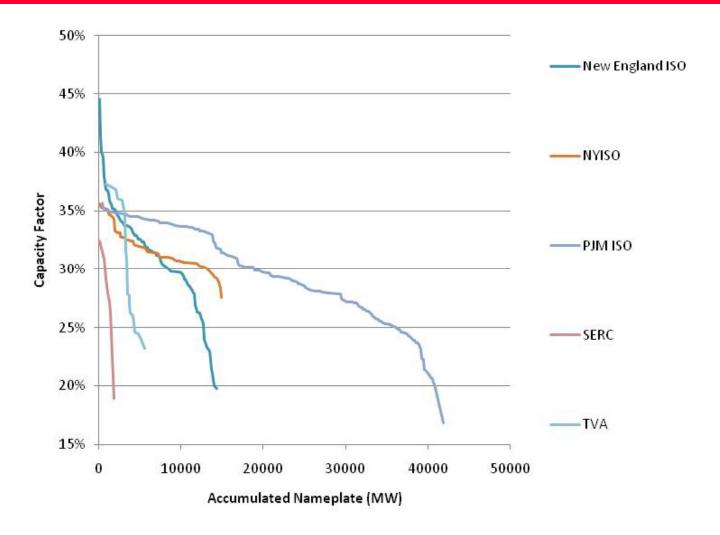


## MISO/MRO/SPP



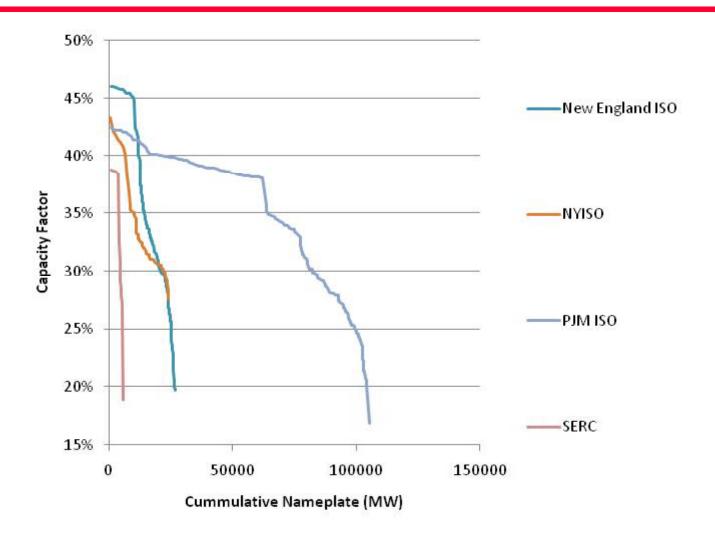


### **Eastern Wind**



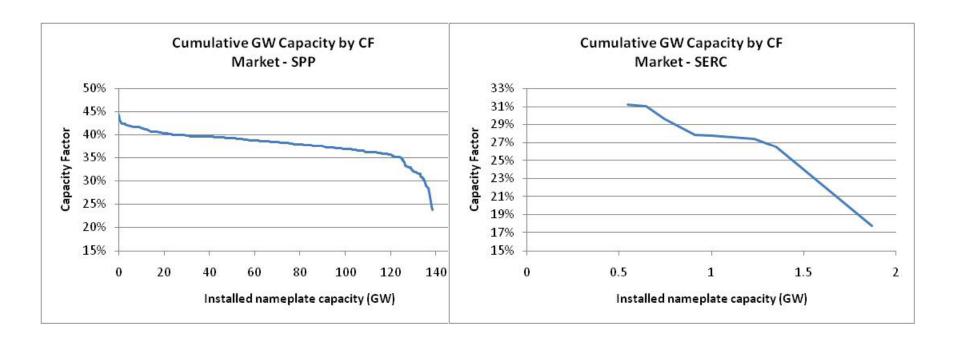


### With Offshore





### SPP/SERC





## **Correlation to Load – Capacity Value**

- Capacity Factor during highest load hours used as proxy
- Calculation by Market Region
- Data
  - Three years of wind production from mesoscale data set (all sites)
  - 2004-2006 load patterns
  - All 26000 hours sorted by load magnitude



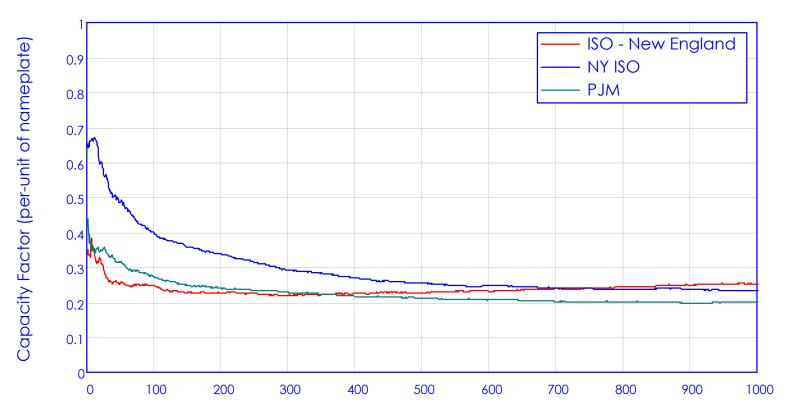
#### **Great Plains & Midwest**







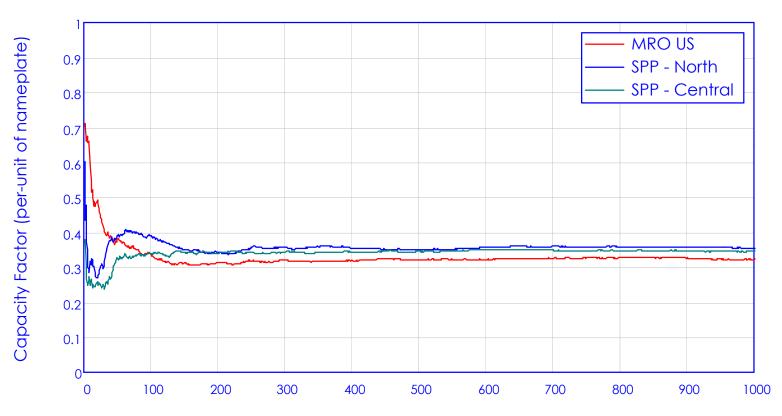
#### **Northeastern US**



Highest load hours over 3-year sample



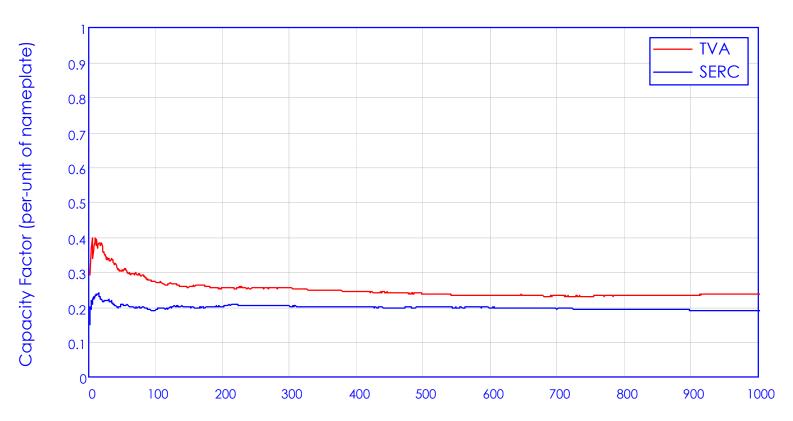
## **West & South**



Highest load hours over 3-year sample



## **Southeast**



Highest load hours over 3-year sample

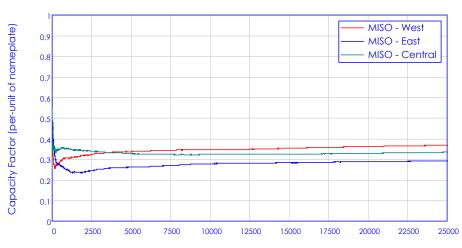


#### MISO – 1000 vs. 26000 Hours

- The cumulative capacity factor curve is much "flatter" that previous seen
- Average capacity

   factor is approached
   after a few hundred
   hours
- Possible causes
  - Very high geographic diversity
  - Very high amounts of wind generation
  - Large data sample 3
     years vs. 1 year
  - Data issues(?)









## **Observations**



# DEVELOPING THE CONCEPTUAL TRANSMISSION OVERLAYS





## **EWITS 2008 Economic Transmission Development**

October 8, 2008 Second TRC Meeting, Wilmington, D.C.



#### **JCSP Economic Planning Process**





Step 1 – Multi-Future Regional Resource Forecasting (Nov 07' – Jan 08')

Step 2 – Site Generation and Place in Powerflow Model (Jan 08' - Feb 08')

Step 3 – Design Prelim. Trans.
Plans for each Future
(March 08' – June08')

Step 4 – Test Transmission Plans for Robustness (July 08' – Dec 08')



Step 6 – Perform Reliability Assessment / Final Design (Jan 09' – Aug 09')

Next JCSP
Tracking and Carry Forward

Step 5 – Consolidate Transmission Plans (July 08' – Dec 08')



#### **Future Scenarios**



#### Reference Future

 Models the Status Quo. This future models the power system as it exists today with reference values and trends based on recent historical data while preserving existing standards for resource adequacy, existing renewable mandates and environmental legislation.

## 20% Wind Mandate Future (Regional/Local)

 Requires 20% of the energy consumption come from wind by 2024. Regional Capacity Factors and capacity credit determined from 2004-2006 actual wind data. Siting based off of higher quality regional sites with required new transmission.

## 30% Wind Mandate Future (Regional/Local)

 Requires 30% of the energy consumption come from wind by 2024. Regional Capacity Factors and capacity credit determined from 2004-2006 actual wind data. Siting based off of higher quality regional sites with required new transmission.



#### **Future Scenarios**



### 20% Wind Mandate Future (Local/Local)

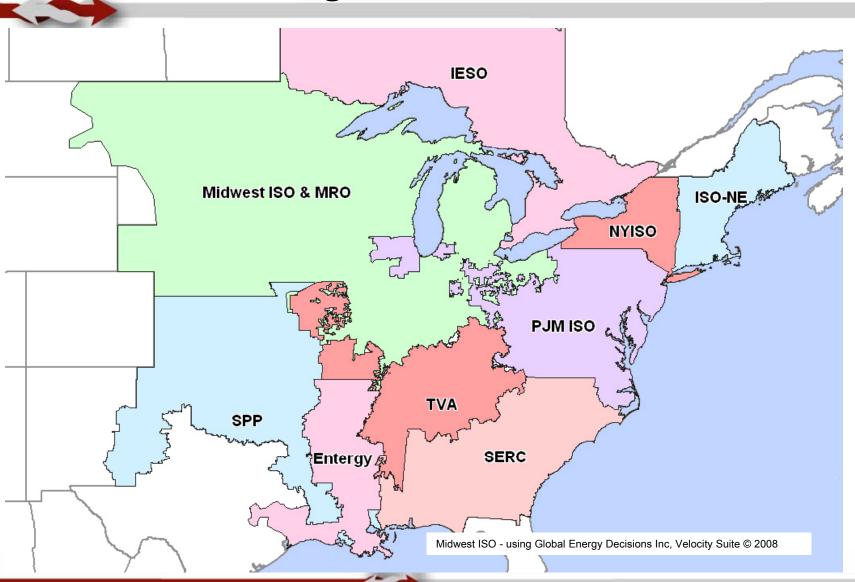
 Requires 20% of the energy consumption come from wind by 2024. Regional Capacity Factors and capacity credit determined from 2004-2006 actual wind data. Siting based off of using more local sites (lower capacity factor) – will represent more installed wind with less required new transmission.

#### 30% Wind Mandate Future (Local/Local)

 Requires 30% of the energy consumption come from wind by 2024. Regional Capacity Factors and capacity credit determined from 2004-2006 actual wind data. Siting based off of using more local sites (lower capacity factor) – will represent more installed wind with less required new transmission.



## **Region Definition**





#### **Generation Assumptions**



Active – Existing online Generation including committed and uncommitted units. Does not include generation which has been mothballed or decommissioned.

Planned - a generator which is not online, has a future in-service date, is not suspended or postponed and has proceeded to a point where construction is almost certain, such as it has a signed Interconnection agreement, all permits have been approved, all study work has been completed, state or administrative law judge has approved, etc.

 These units are used in the model to meet future demand requirements prior to the economic expansions



#### **Generation Assumptions**



Only known retirements are assumed for the study

Re-licensing is assumed on all Nuclear Units

Proposed Nuclear Additions are treated as "planned" units in the study, meaning they are assumed to be moving forward, and appear in each future



#### **Demand Response & Energy Efficiency**



Demand Response is represented by the Interruptible Demand & Direct Load Control in the Default PowerBase with adjustments made by individual Stakeholders

The 2008 level of participation for Demand Response is maintained for the 20 year study period.

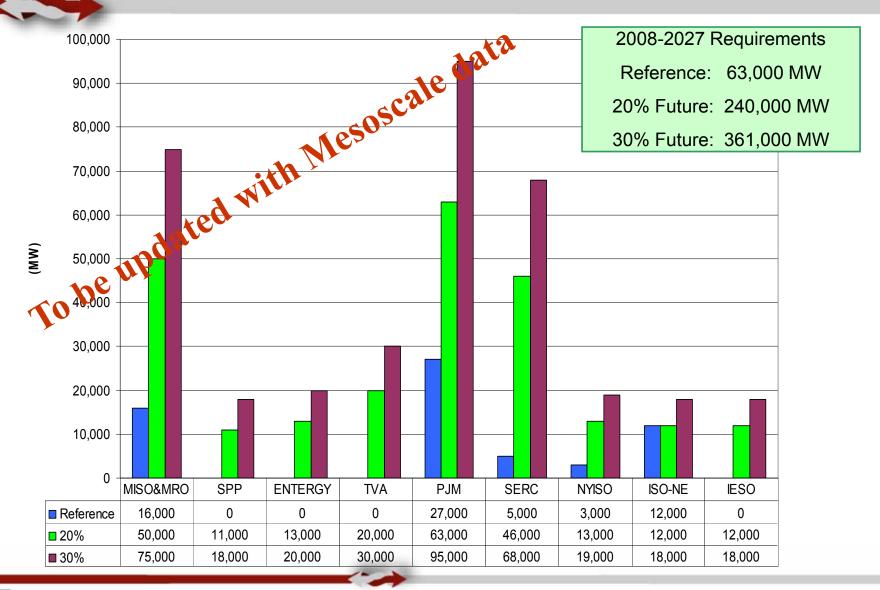
Energy Efficiency is not modeled as an uncertainty

Assumed Annual Demand Response Additions (MW)							
PJM	73.2						
ISO-NE	70.0						
TVA	64.7						
MISO West Region	58.3						
SERC	51.5						
NYISO	20.0						
SPP	10.5						
MISO Central Region	8.2						
MISO East Region	7.9						
IESO	1.8						
MRO US	1.6						
ENTERGY	1.1						





#### 2008-2027 (Study Period) Incremental Regional Wind Requirements





## Perform Resource Forecast Expansions

Once the siting of the wind capacity is known and completed on a regional basis, the regional resource capacity expansions will be performed:

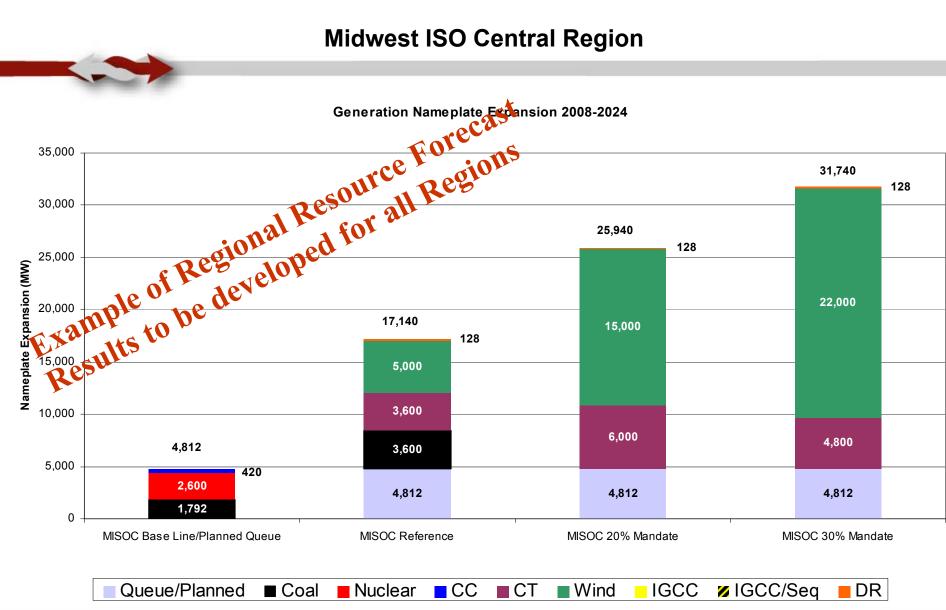
20% Regional/Regional 30% Regional/Local

20% Regional/Regional 30% Regional/Local





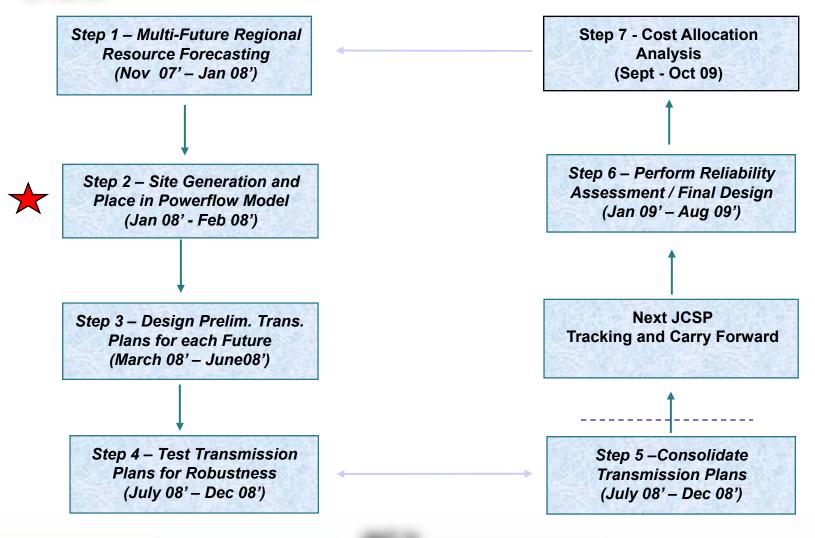






#### **JCSP Economic Planning Process**







#### **General Siting Methodology**

Transmission is not an initial siting factor, but may be used as a weighting factor all things being equal

Site by region with the exception of wind

"Share the Pain" mentality. Not all generation in a region can be placed in one state and one state cannot be excluded from having generation sited

Avoid Greenfield Sites for gas units (CTs & CCs) if possible - prefer to use all Brownfield sites

Site baseload units in 600 MW increments, & Nuclear at 1,200 MW

Limit the total amount of expansion to an existing site to no more than an additional 2,400 MW

Restrict greenfield sites to a total size of 2,400 MW

Limit using Queue generation in multiple futures



#### **Thermal Generation Site Selection Priority Order**



Priority 1: Generators with a "Future" Status

- Queue Generators without a Signed IA
- Global Energy's "New Entrants" Generators Will be referred to as "EV" Gens
- Both Queue and EV Gens are under the following status:
  - Permitted
  - Feasibility
  - Proposed

Priority 2: Brownfield sites (Coal, CT, CC, Nuclear Methodology)

The following Priorities not triggered in JCSP context:

Priority 3: Retired/Mothballed sites which have not been re-used Priority 4: Greenfield Sites

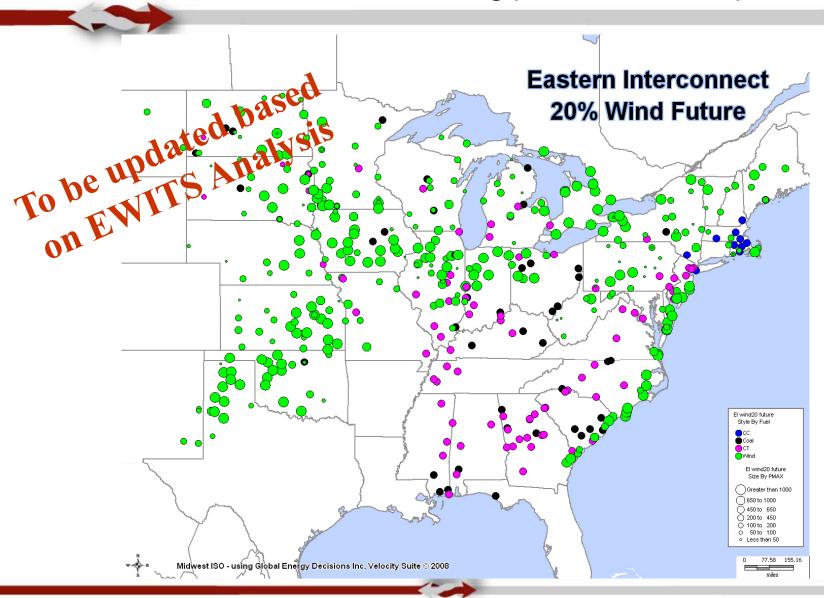
Queue & "New Entrants" in Canceled or Postponed Status

Priority 5: Greenfield Sites

Greenfield Siting Methodology



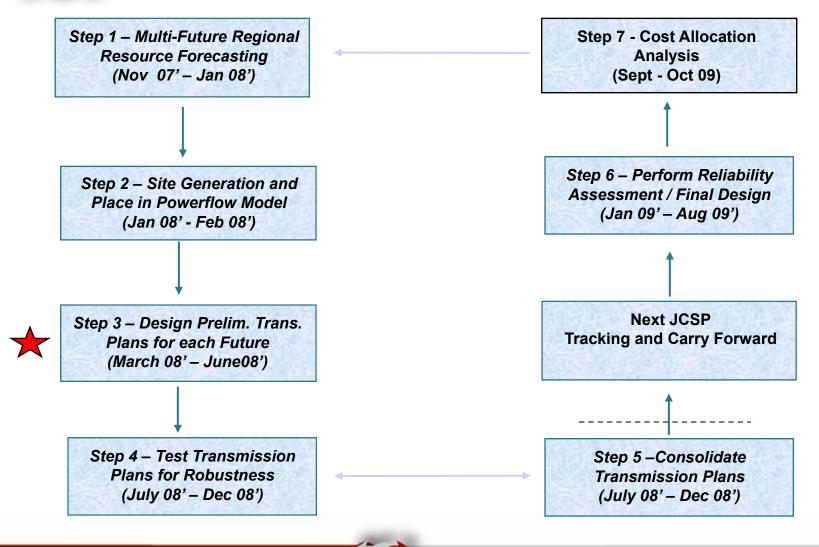
#### **Renewable Future Siting (20% Wind Mandate)**





#### **JCSP Economic Planning Process**







## Hold Transmission Design Workshop(s)

TRC members will form the transmission design workshop participants.

One or possibly two meetings with the TRC members will be held to develop all required overlays.

Same process used as in the JCSP transmission design workshops.



#### Schedule/Process for Developing Transmission Overlays

	Se	pt	October				November				December					Jan
	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5
2nd TRC Meeting																
Scenario Definitions																
20% Regional																
30% Regional					<b></b> →											
20% Local					<b>→</b>											
30% Local					$\longrightarrow$											
Wind locations mapped																
Capacity credit determi																
RRF Expansions (EGEAS	)							<u> </u>								
Siting of RRF capacity										<del></del>						
PROMOD model comple	te										<u> </u>					
Initial PROMOD runs use	ed for														$\longrightarrow$	
transmission desi	gn															
Workshop - Transmissi	on des	ign w/	TRC													
Green is Enernex work																
Blue is MISO work to be	perform	ned			2 Marie 1											



# METHODOLOGY FOR CONSIDERATION OF INTRA-HOURLY OPERATIONS



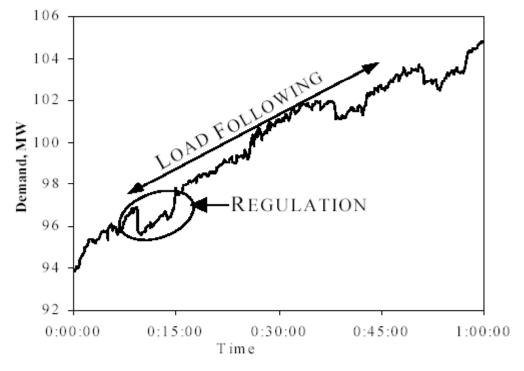
#### **Reserve Issues for Wind Generation**

- Wind generation increases variability of net balancing authority demand
- Additional reserves required to meet control performance standard
- Contingency reserves usually unaffected
- Elements
  - "Regulation" for frequency support, balancing
  - Capacity held in reserve due to uncertainty, e.g. schedule deviations and short-term forecast error



## **Load Following & Regulation**

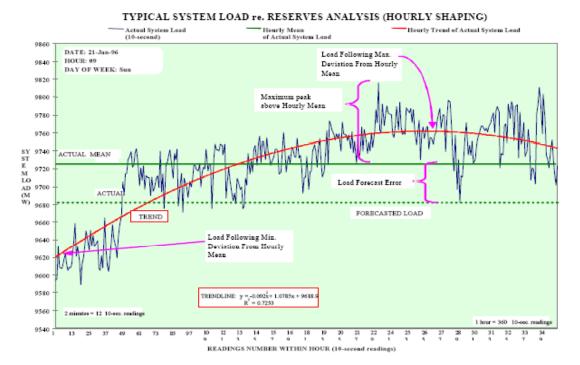
- Load changes within the hour segregated into two temporal components
- Regulation
  - Fastest variations that are corrected by automatic actior
  - Non-economic unit movemen
  - Primarily a capacity requirement supports interconnection frequency
- Load following
  - Responding to
    - » intra-hour load trend
    - » slower deviations from tr
  - Flexible units are dispatched economically to meet changing requirements (5 to 10 min.)

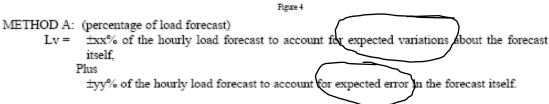




### **WECC White Paper on Operating Reserves**

- Describes approaches for determining required amount of hourly regulating reserve
- Method "A"
  - Variability component
  - Uncertainty component
- Easily extended to consider wind generation





Based on a control area's experience, xx might be ≈1% of the daily peak load forecast. For control area's that perform daily load forecasts, yy is typically 3%. For control areas that use adaptive load forecasts executed every hour, yy could average slightly less than 2% with hourly ranges of <1% to ≈5%. For this smethod the expected changes whereing the hour are applied for all 10-minute intervals.

October 8, 2008

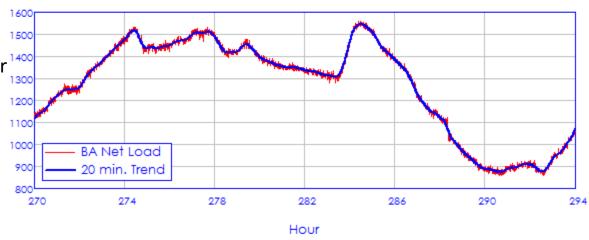
Slide #66



## Regulation vs. Load Following

- Fastest variations in demand changed little by wind generation
- Impacts more apparent over tens of minutes (depending on wind generation scenario)
- Wind variability tends to make hourly reserve requirement "symmetrical"
  - +/- hourly average
  - Load is more unidirectional
- ◆ Is this increased Regulation or Load Following?







#### **Methods**

- Methodology based on simulation of system operation over extended period (year or years)
- Must capture scheduling and real-time operations
- Hourly granularity of simulations necessitates separate analysis of intra-hour impacts
  - e.g. incremental reserve requirements with wind generation

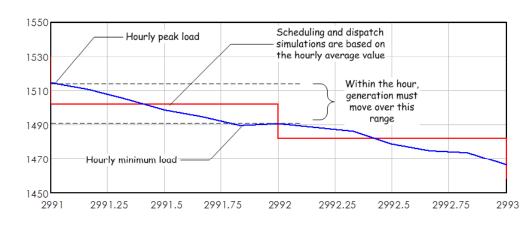


## **Analyzing Inside-the-Hour Impacts**

- Based on high-resolution load and wind data
  - 1-minute load data from archives
  - 5-minute wind generation data, with estimates of higher-resolution behavior from measurements
- Objectives are to determine:
  - Incremental regulating requirements due to wind generation
  - Additional maneuverability or flexibility to balance control area with wind (e.g. "load following")
- Results are brought forward to hourly simulations
  - Not modeled explicitly because of hourly time step
  - Serve as new constraints that must be honored in commitment and dispatch

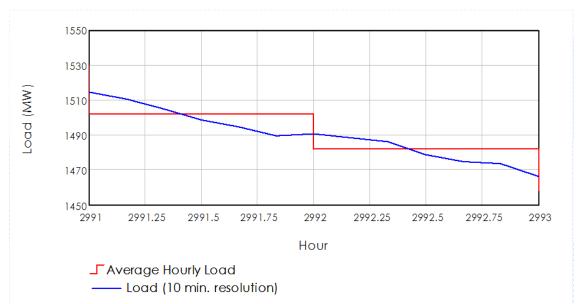


## **Production Simulation vs. Reality**



Hour

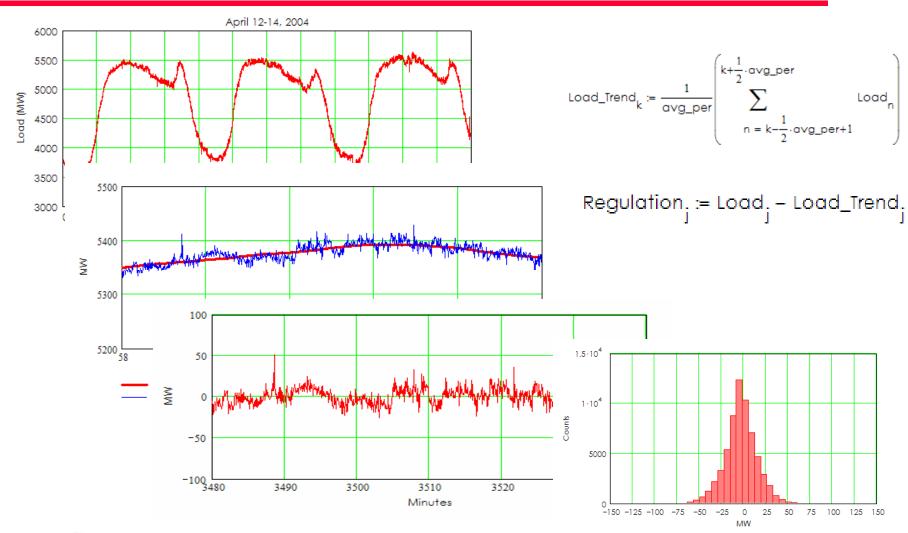
Average Hourly Load
Load (10 min. resolution)





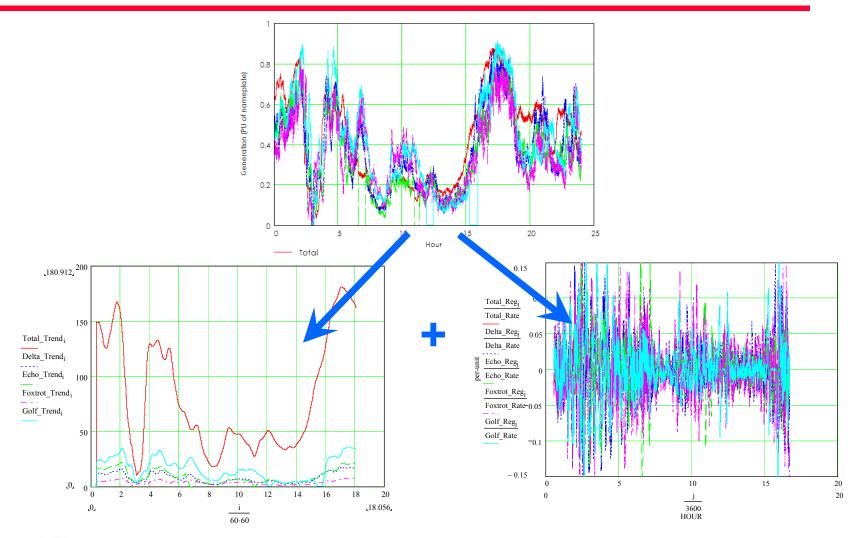
Load (MW)

# Determining the "Regulation" Characteristic of the Existing Load





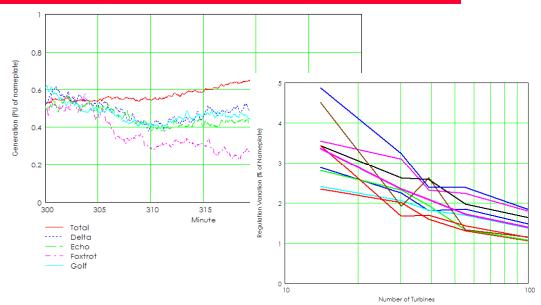
## **Extracting the Regulation Characteristics from Wind Generation Measurements**





## Increased Regulation Demand with addition of Wind Plants to Control Area

- Assumption of statistical independence simplified the problem
- Addition of wind generation would lead to small increase in std. deviation of regulation demand
- Regulation requirement can be roughly equated to 3\*sigma
- Example: Increased RR would be just under 8 MW



$$\sigma_{T} = \sqrt{\sum \sigma_{i}^{2}}$$

$$\sigma_{T} := \sqrt{\sigma_{L}^{2} + 50 \cdot (\sigma_{Wi}^{2})}$$

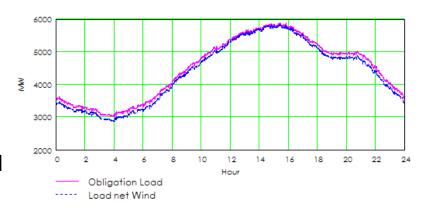
$$\sigma_{L}^{\prime} = 20.2 \,\text{MW}$$

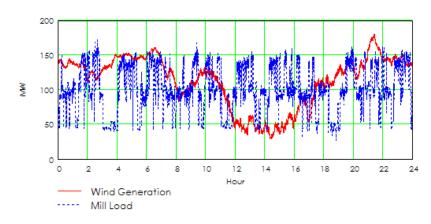
$$\sigma_T = 22.8 MW$$



## **Findings to Date**

- Increases in regulation requirements (remember definition) due to even large amounts (15%) of wind generation appear to be quite small
- Large turbine count and geographic diversity contribute to substantial "filtering" of these fast variations in wind generation output
- Lack of correlation to system load also contributes to modest impact
- Some types of (much smaller) loads can have much greater influence on regulation requirements
  - Right: System with wind generation and arc furnace load
  - Mill load dominates regulation needs







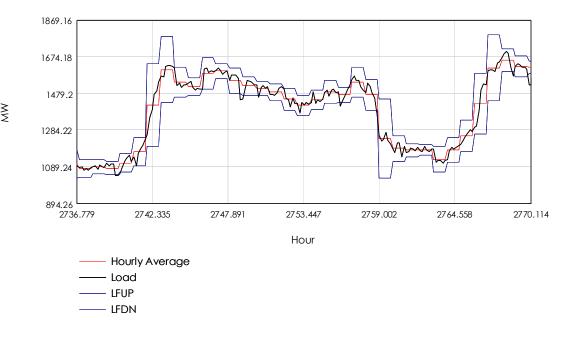
## Other Variability inside the Hour

- Regulation is a capacity service (net energy is zero) and requires AGC
- Slower variations covered by frequent economic re-dispatch of maneuverable units; capacity & energy service
- Wind generation has influence on this variability as well



## **Approach**

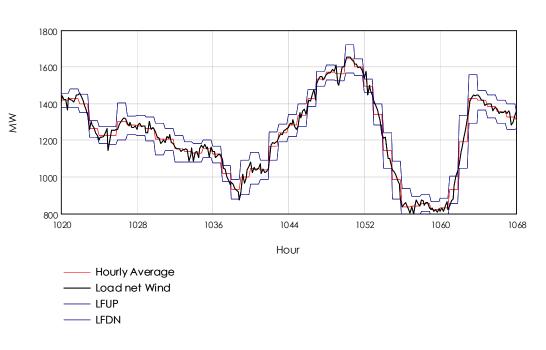
- Determine generation capacity required to compensate for deviations of 10-minute load from hourly average or other smoothed characteristic
- Capability will vary by hour (profile rather than number)
- >90% of deviations must be within hourly capability plus APS L10 (pseudo "CPS2" evaluation)





## **Analyze Load net Wind Generation**

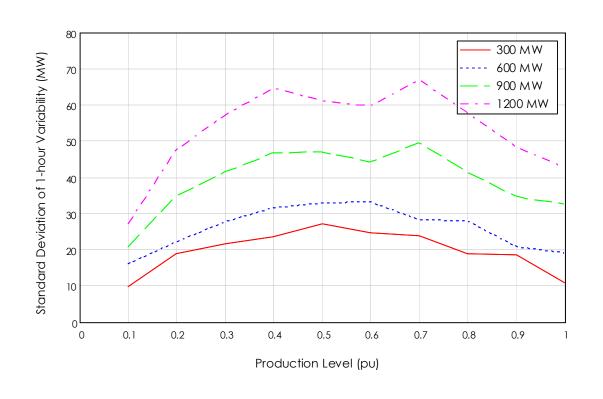
- Increased net variability
   will add to
   maneuverability
   requirement
- Modify load following "rule" to match loadonly performance





## **Accounting for Wind Variability**

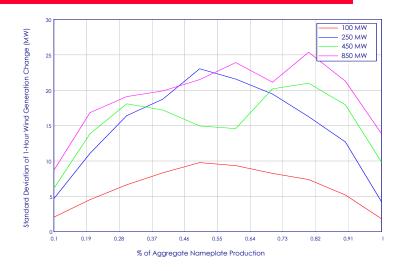
- Expression added to "load following" equations accounts for incremental intra-hour variability due to wind
- Expression is a function of wind generation production level in current hour
- Developed from wind generation data

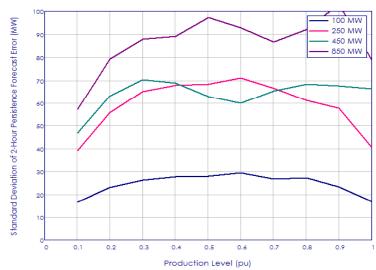




## **Analytical Approach**

- Analyze high-resolution (5-min.) wind and load data to extract variability metrics
- Apply methodology similar to WECC white paper to determine hourly flexibility necessary to manage system
- Test results against high-resolution wind and load data
- Fast markets could also be considered
  - "economic" levels defined at each 10minute interval
  - Regression load forecast + persistence wind
  - Deviation from this point falls to fast regulation duty (spinning)



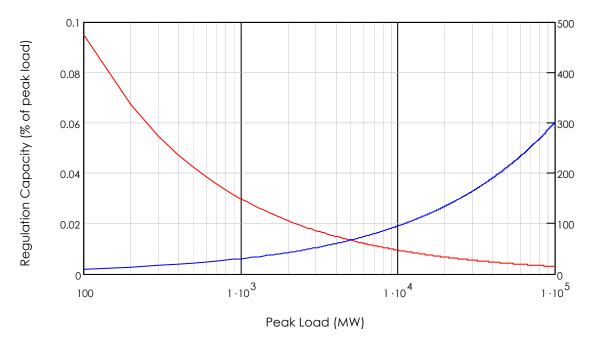




#### **Control Area Size matters...**

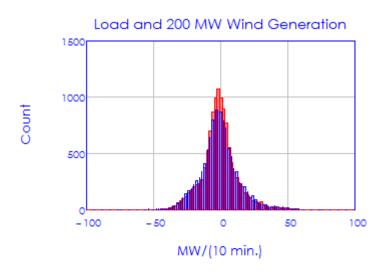
- Larger control areas benefit more from load aggregation and diversity
- Faster fluctuations are smaller fraction of load
- Applies with wind as well

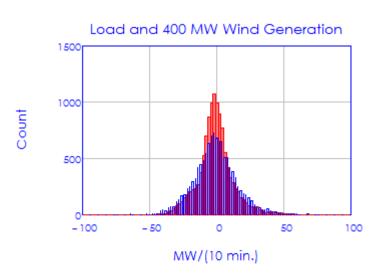
#### Regulating Requirements vs. Control Area Size





## Incremental Balancing Burden – Small Balancing Area



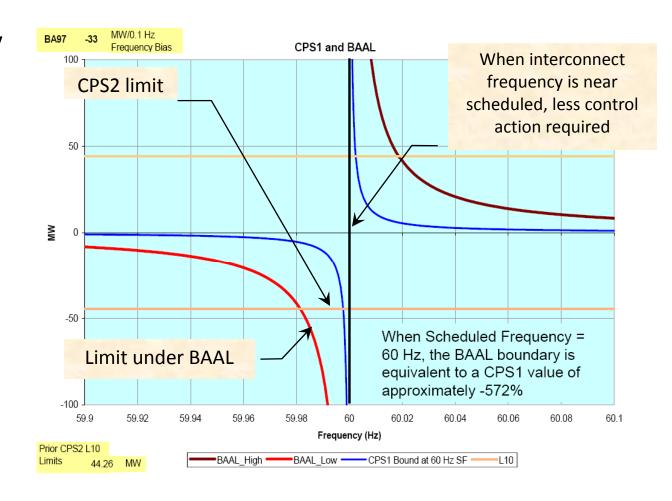


Case	% of changes > 50 MW in 10 minutes	% of changes > 25 MW in 10 minutes
Load Only	0.58%	8.48%
200 MW	0.71%	9.93%
300 MW	0.97%	11.72%
400 MW	1.16%	13.98%
700 MW	2.50%	19.60%
1200 MW	4.95%	26.88%



# **Proposed Control Performance Standard - BAAL**

- Balancing Authority Area Limit
- Would have significant implications for balancing with wind in small Bas
- Inadvertent would become mechanism for spreading imbalance





## **Addressing Variability**

#### Conventional

- "RegUp/Dn" capacity deployed quickly and un-economically to support interconnection frequency
- Load following, maneuverable generation resources dispatched economically at frequent intervals to follow load trend

#### Market Mechanisms

- Real-time Energy markets
- Ancillary Services markets
- Traditional regulation



# Total Regulating Reserves – **Proposed Approach for EWITS**

- Estimate operating area regulation requirement from chart (previous slide)
- Assume that all operational footprints have day-ahead and fast (e.g. 10 minute) energy markets
- For each scenario, calculate additional regulation (additive) requirement as difference of
  - 10 minute forecast interval based on forecast 15 minutes prior to interval
    - » Load projection based on regression
    - » Wind projection based on either persistence or regression
  - Actual load net wind data for interval
- Additional non-spinning reserve calculated to cover significant expected reductions in wind generation



## **Contingency Reserves and Other Issues**

#### Questions

- Reserve sharing pool definitions?
- Criteria
  - » Largest hazard?
  - » What about dc terminals?
- Would BAAL affect requirements dramatically?

#### Other issues

- How to make very high penetration areas "work"
- Contribution to reserves by dc terminals
- Co-optimization or allocation of energy schedules and reserve duty on dc lines



## **Discussion & Summary**

- Intra-hourly methodology
- Operating assumptions
- Mapping results to available reserve categories



# HOURLY PRODUCTION SIMULATIONS – APPROACH, ISSUES, ASSUMPTIONS



## **Overview of Issues & Assumptions**

- Market Structure(s)
- Treatment of non-market areas
- Representation of Canadian utilities
- Modeling questions
- Critical inputs



#### **Markets**

- Market structure may have influence on
  - Operating reserve requirements and estimation from highresolution data
  - Hurdle rates between areas
- How many markets in 2024?
- What products will be available in each?
- Should we assume uniformity, or is there reason to vary the market model across the Eastern Interconnection footprint?



#### **Other Structural Questions**

- What about non-participants?
- What about Canadian Utilities



## **Modeling Questions & Challenges**

- Production simulations conducted at hourly granularity
- Requirements for operations within the hour represented as constraints
  - Contingency reserves
  - Regulating reserves
- Methodology for estimating in-hour reserves for PROMOD?



## **Modeling Questions & Challenges**

#### Forecast horizon

- Presently, day-ahead optimization/commitment is the norm
- Forecast errors lead to sub-optimal commitments
- With significant wind generation
  - » Will DA forecast errors with significant wind generation be too large to permit reasonable optimization?
  - » Is a shorter commitment horizon warranted? (e.g. All-Ireland Grid Study)

#### HVDC line modeling

- Based on JCSP, large a significant component of transmission overlay
- What will be the "rules" for scheduling transactions and services at the terminals?



### Summary

- Modeling assumptions and inputs will become critical path following TRC Meeting #2
- Topics will be discussed again at that meeting
- Project team will provide recommendations for review





#### PROMOD Wind Integration Methodology EWITS TRC Meeting

Wilmington, DE October 8, 2008

#### **Overview Of Upcoming Ventyx Activities**

- Initial testing/review of JCSP 5% Base Line scenario
- Construct and validate NREL hourly wind profiles
- Implement Results from Enernex Sub-Hourly Analysis
  - Operating Reserves
  - Reserve Margin Capacity Value
  - Load Forecasting Error
  - Wind Forecasting Error
- Assist MISO by running PROMOD IV to provide feedback on development of transmission overlays



#### **Development of Base Line scenario**

- Work with MISO to reproduce JCSP 5% scenario as Base Line for EWITS
- Work with MISO/Enernex to refresh data assumptions
  - Fuel Prices
  - Near-term generation expansion
  - **▶** Emissions assumptions
- Optimize PROMOD IV run-time
  - Move to latest PROMOD IV version
  - Reduce program dimensions to minimize memory requirements
  - Review model settings, options, and data construction for efficiency
- Test recent improvements for modeling wind generation



#### **NREL Hourly Wind Profiles**

- Construct new datasets with NREL hourly wind profiles
- QA wind profile data
  - Capacity Factors
  - Geographic Diversity
  - Seasonality
- Assess impact on new wind profiles on results
  - ► Thermal unit generation changes
  - Congestion impacts
  - Production cost impacts



#### **Implement Results of Sub Hourly Analysis**

- Operating Reserves
  - PROMOD IV reserve modeling
  - Contingency Reserves
  - Regulating Reserves
  - Reserve Regions
- Reserve Margin Capacity Value
  - Impact on thermal unit expansion



#### **Implement Results of Sub Hourly Analysis**

- Load Forecasting Error
  - By area, allocated proportionally to load buses
  - Based on research of historical data
- Wind Forecasting Error
  - Persistence Forecast Methodology
  - ► Implemented at wind site/zone



#### **Support of MISO Transmission Overlay Development**

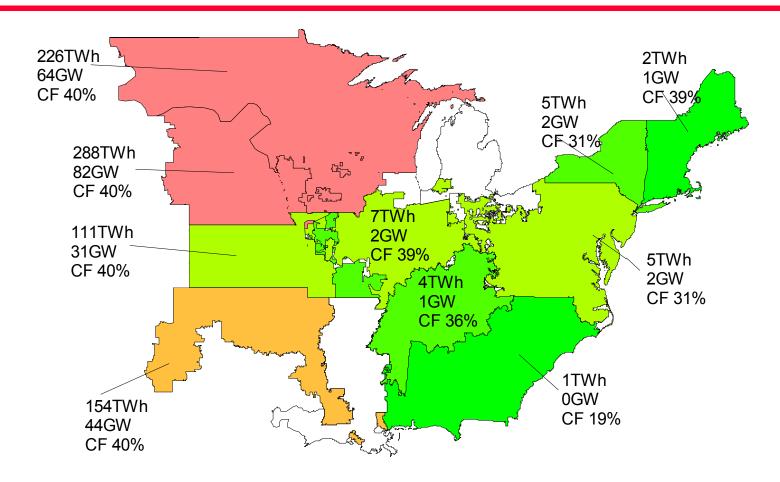
- Provide Base Line updated Base Line scenario as starting point for MISO
- Advise MISO on modeling multi-terminal DC lines, modeling export of wind volatility, and other aspects of overlays
- Assist in running PROMOD IV cases as needed to support MISO overlay development process
- Perform related tasks such as contingency analysis, diagnostic model runs, or data research



# PROPOSED WIND GENERATION SCENARIOS

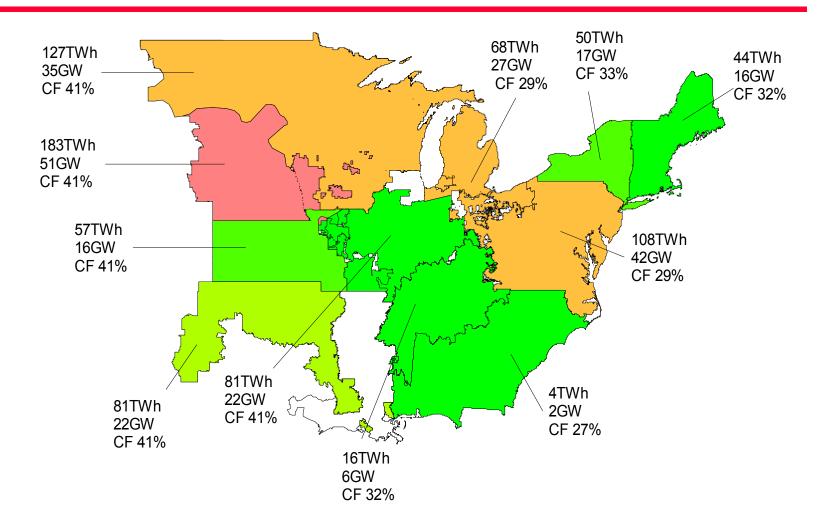


#### 20% Base Scenario – Best Wind



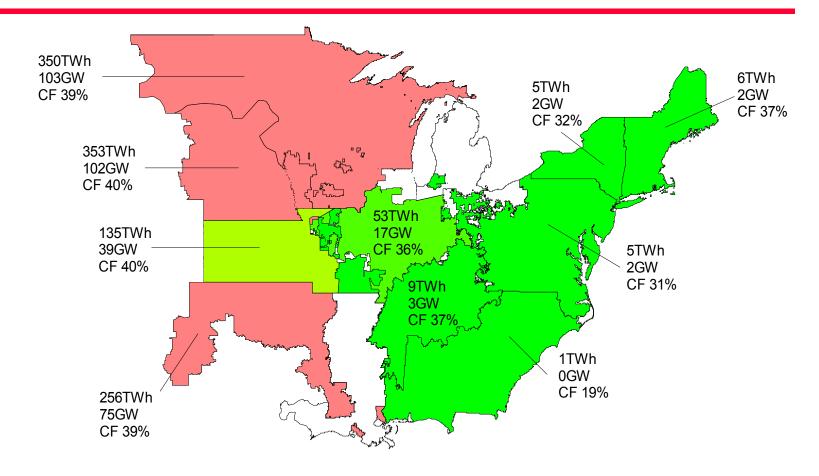


#### 20% Alternate Scenario – Load Centered



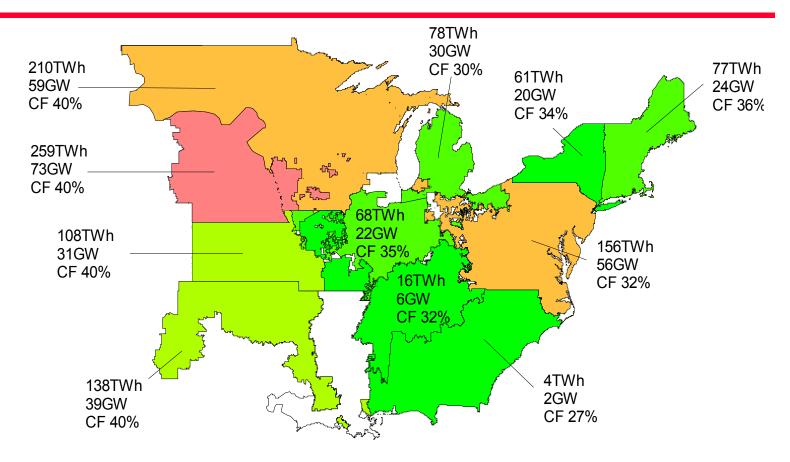


#### 30% Base Scenario – Best Wind





#### 30% Alternate Scenario – Load Centered





### **Scenario Statistics**

#### 20% BEST WIND

RegionName	Reference Energy (GWh)	Nameplate (MW)	CF
MISO West	225681	64111	40%
MRO US	288143	81691	40%
New England ISO	2426	719	39%
NYISO	5088	1849	31%
PJM ISO	5226	1948	31%
SERC	703	423	19%
SPP Central Region	154136	43719	40%
TVA	3987	1248	36%
MISO Central	6808	1992	39%
SPP North	110883	31496	40%
Total	803081	229195	40%

#### 30% BEST WIND

RegionName	Reference Energy (GWh)	Nameplate (MW)	CF
MISO West	349750	102513	39%
MRO US	353327	101734	40%
New England ISO	5704	1737	37%
NYISO	5401	1949	32%
PJM ISO	5226	1948	31%
SERC	703	423	19%
SPP Central Region	256034	75058	39%
TVA	9258	2886	37%
MISO Central	53097	16638	36%
SPP North	134889	38800	40%
Total	1173389	343686	39%

#### 20% ALTERNATE

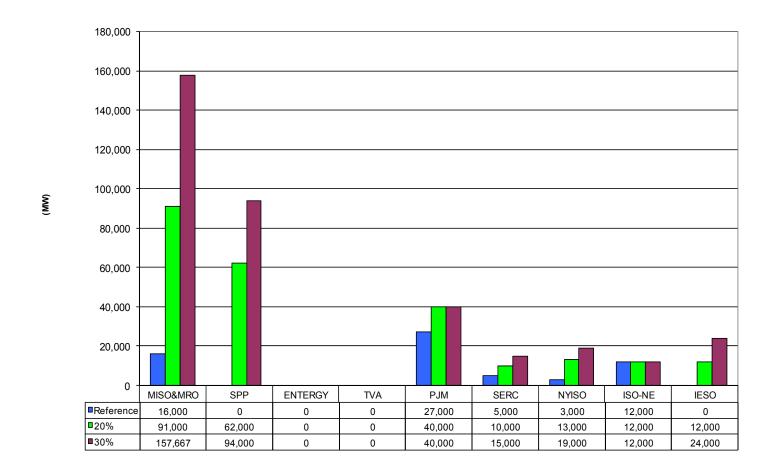
RegionName	Reference Energy (GWh)	Nameplate (MW)	CF
MISO West	126546	35309	41%
MRO US	183020	51112	41%
New England ISO	43785	15657	32%
NYISO	49862	17359	33%
PJM ISO	108252	41892	29%
SERC	4442	1870	27%
SPP Central Region	81153	22421	41%
TVA	15520	5561	32%
MISO Central	44192	14462	35%
Miso East	68028	26538	29%
SPP North	57480	16077	41%
Total	782281	248260	36%

#### 30% ALTERNATE

RegionName	Reference Energy (GWh)	Nameplate (MW)	CF
MISO West	209664	59373	40%
MRO US	258995	73066	40%
New England ISO	76699	24017	36%
NYISO	60513	20399	34%
PJM ISO	156323	55652	32%
SERC	4442	1870	27%
SPP Central Region	138441	39070	40%
TVA	15520	5561	32%
MISO Central	68336	22326	35%
Miso East	77771	29598	30%
SPP North	108493	30787	40%
Total	1175197	361718	37%



#### **JCSP 20% Case**





#### **Discussion**



## **DISCUSSION & WRAP-UP**



## **Outstanding Issues**

- Intra-hourly Modeling
- Base and Alternate Scenarios
- Capacity Expansion Planning for Overlay Development
- Developing the Transmission Overlay Concept
- Production Modeling for Integration Analysis



## Wrapping Up

- Miscellaneous discussion
- Review of Action Items
- Meeting follow-up
- Next meetings

